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TEST OF MULTIPLE SHAPED
CHARGE TERRIER WARHEAD

TECHNICAL MEMORANDUM
NUMBER V
FEBRUARY 10, 1956

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CONTRACT NUMBER

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EXPLOSIVES RESEARCH GROUP
INSTITUTE FOR THE STUDY OF RATE PROCESSES
UNIVERSITY OF UTAH
SALT LAKE CITY

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TEST OF MULTIPLE SHAPED CHARGE TERRIER WARHEAD

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Technical Memorandum V

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TERRIER WARHEAD TEST

Description of the Warhead

The following report describes the results of a simulated test against aircraft structures of a Terrier Warhead replica employing multiple shaped charges. As is the case with most designing, the liner element dimensions were a compromise between those most desirable on the basis of experimentation and those which could actually be fitted into the warhead.

A diagram of the warhead replica showing a top view is given in figure 1. It was cylindrical in shape having a 13" diameter and 16" length. The warhead was made in two sections in order to make comparisons of two types of liners. One hemicylinder consisted of 12 cone liners with opposite sides beveled such that they would fit the cross-sectional dimension of the 13" diameter. They were arranged in four columns, each containing 3 liners. The other hemicylinder was made up of 1/3 pipe liners. The 1/3 pipes were constructed by splitting a 16" long, 3 1/2" outside diameter, 2 1/4" inside diameter aluminum tube along its axis to form three identical 16" length sections. Eight of these were mounted in one hemicylinder of the warhead. Aluminum was used for both the 1/3 pipes and the cones because it was the most effective material to produce damage of aircraft sections we had found at the time of the construction of this warhead.

The cone liners were machined from round aluminum stock. They were 5" in diameter with 135° apex angle and a wall thickness of 1.12". This wall thickness was calculated by means of the detonation head model to allow the optimum transfer of kinetic energy from the explosive to the liner for an axially initiated cylindrical composition B charge 13" in diameter, less 3" at the center for the initiator. Experiments conducted at this laboratory have substantiated this calculation. The cone angle was a compromise between a more pronounced jet effect for smaller angles and room for more explosive in the warhead provided by large angles. Experimental work in this laboratory has shown that 90°-100° angle cones are the most

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effective at the standoffs of interest here, although if a very high pressure explosive such as composition B is used, the 135° cones are nearly as good as the narrower ones. For this reason composition B was used in this test. The cone diameter chosen was a compromise between more damage at greater standoff for large diameter cones and more room for explosive in the warhead with great hit probability for smaller cones. In order to provide a small amount of additional explosive volume and to conserve aluminum stock, the tip of each cone was machined off 0.3". This evidently produces no adverse effects for long standoff.

The region between the cones was filled with Devcon which is a steel powder impregnated plastic. This not only was a convenient method of holding the cones rigidly in place but also provided a surface density between the cones which was approximately equal to that exhibited by the cones.

The warhead was initiated with a 16" Model I axial initiator. To provide space for the initiator a 3" diameter cardboard tube was installed coaxially in the warhead before casting. Just prior to firing the initiator was installed in this volume.

Target Area Description and Damage Results

The test was carried out at the Tooele Ordnance Depot firing site maintained by the Explosives Research Group. The targets consisted of F-84 wings which are 8 ft. wide at the base, 18 ft. long and weigh 700 lbs; B-17 horizontal stabilizers 8 ft. wide at the base, 18 ft. long, weighing 150 lbs.; and F-84 ailerons. These targets were obtained from Hill Air Force Base, Ogden, Utah, through arrangements made by the Bureau of Naval Ordnance.

A schematic diagram of the firing area showing the target and warhead locations is given in figure 2, and figure 3 is a photograph of the setup before firing. The targets were located at standoffs ranging from 30 ft. to 120 ft. For convenience in discussing the damages, each of the targets with the exception of the ailerons was assigned a number. The

target numbers of the aircraft surfaces are given in figure 2 as well as on photographs showing damages. In addition each of the surfaces was assigned a letter which designated its orientation. The letter S signifies the surface was placed on its side (the side being the long dimension), and lying in a vertical plane. The letter E means the surface was placed on its end (the end being the shorter dimension), and lying in a vertical plane. The letter E_t signifies the surface was placed on end and tipped approximately 30° - 45° from the vertical. The amount of tipping for any given surface may be estimated from figure 3.

The detonation was photographed by two 4" x 5" cameras designated C_1 and C_2 on figure 2. The shutters of these cameras were solenoid operated from the ERG instrument shelter, which was about 1000 ft. from the warhead. The opening of these shutters completed the circuit which triggered the detonation, thus ensuring the event would occur when the shutters were open. In addition, the detonation was photographed by a fastax camera mounted at the instrument shelter.

Figure 4 is the photograph taken by camera C_1 during the explosion. Although it is overexposed, the streaks of light from the jets can be distinguished, and their trajectories show the initiator functioned satisfactorily. Examination of the fastax pictures verified this conclusion. Figure 5 is an overall view of the test area immediately after detonation of the warhead, and figure 6 contains a series of closeups of the targets after they have been restored approximately to their pre-firing positions. Targets 10, 20, and 21 were not perforated and hence are not shown. An idea of the damages accomplished at various distances may be obtained by examining the pictures in figure 6 and noting the target locations given in figure 2.

As might be expected, target number 15, which was only at 30 ft. stand-off from the 1/3 pipes and 45° incidence, was demolished. More than 50 percent of the skin area was completely torn away. Although the target evidenced blast damage, most of the damage should be attributed to material

from the 1/3 pipe to which it was exposed. This may be concluded from the picture, because the damage was concentrated around the area hit by the jet. Target number 16, 15 ft. behind number 15, sustained little damage. Target number 14, 45 ft. from a 1/3 pipe section and normal standoff, suffered severe damage. Much of the skin and stringers were torn away and most of the rivets broken loose. Target number 18, 15 ft. behind number 17, contracted only minor perforations. Nearly all the energy from the 1/3 pipes was evidently expended in the first targets. The damage accomplished by the 1/3 pipes on the other sections was only minor. The wing section, target number 11, at 45 ft. standoff and 45° incidence did not suffer much damage. This was probably due to two reasons: 1) the wing was of sturdier construction than the stabilizers; 2) the top panels of the wing had been previously removed, and we were able only to re-install them loosely. Thus these panels were blown off before any measurable pressure could be generated within the structure by the jet.

The damages produced by the cones may be determined by examination of the target damage photographs for targets number 1 through 9. The stabilizer sections at 60 ft. standoff, target number 4, which was on its end and tilted about 30° from the vertical (60° angle of incidence), and target number 8 which was on its side and at 45° incidence, suffered extensive damage. In both cases a large section of skin was torn away by the jets. Most of the stringers were broken, some ribs were crumpled, and nearly all the rivets supporting the skin were torn loose, which indicated that considerable pressure was generated within the structure. At 90 ft. and 120 ft. standoff (targets 2, 3, 5, and 9) only relatively small perforations were produced. Somewhat greater damage was sustained by target number 1. A number of fairly large holes were produced upon the emergent face and most of the rivets fastening the skin to the ribs and stringers were torn loose. Target number 6, the wing section exposed to the cones, sustained some good damage. However, as mentioned with the other wing, target number 11, the top panels had been previously removed and we were unable to refasten them securely. As a consequence, they blew off before any damage could be extracted due to pressure within the structure.

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The effectiveness of the cones with respect to the 1/3 pipes may be ascertained by comparisons of targets 4 and 5 with 19 and 20, targets 8 and 9 with 13 and 14, and targets 6 and 7 with 11 and 12. These comparisons favor the cones in all cases. Thus at long standoff or against sturdy structures the cones were evidently more effective than the 1/3 pipes. It should be kept in mind, however, that the 1/3 pipes were of smaller width than the cones, and in spite of this were quite effective up to 45 ft. standoff.

Evaluation of Results

An accurate evaluation of the K-kill probability of the warhead tested is very difficult. It is true that criteria have been established whereby a number may be assigned to the K-kill probability of a given liner and charge against a particular aircraft at a given standoff. The validity of such analyses may be open to question, however. For instance, some investigators in this country conclude K-kills are possible only with cones of 6" minimum diameter, and they believe that 8 1/2" diameter cones may be necessary.

Our work against B-17 stabilizers at 60 ft. standoff indicates that 5" diameter, 135° aluminum cones can consistently produce results comparable with those shown in the literature as K-kill damage, if the charge is a wedge-shaped segment from a cylinder, and is initiated from the apex by our Model II axial initiator. However, until heavier aircraft sections are obtained, our K-kill estimates must be withheld.

The K-kill probability for a warhead may be expressed as

$$P_k = P_h P_k$$

where p_h is the hit probability and p_k is the K-kill probability as previously defined. It is not a difficult matter to calculate p_h for a given aircraft and standoff provided proper initiation is attained. One merely calculates the solid angle subtended by the aircraft at the standoff distance.

in question. Nonvulnerable areas such as the wing tips, trailing edges, rudder, etc., are not included in calculating this solid angle. The probability of a hit is then merely the probability a jet will traverse within this solid angle. If the aircraft in question were of the B-29 type, about 18 equally spaced columns of cones would be the minimum required for $p_h = 1$ at 60 ft. standoff. For a warhead consisting of cones of the size used in this test and in which the cones were mounted in 8 columns of 3 each, p_h would equal about 4/9. This of course could be doubled if the rows were staggered so as to form 16 columns.

It is necessary that a symmetrical wave contact each cone in order to produce good jet performance. The axial initiator we have developed seems to be very reliable in this respect. In fact, individual cones in wedge-shaped charges initiated by means of 8" cylindrical initiators exhibit as good jet performance as cones in the ends of cylindrical charges which are point-initiated at the opposite end.

Recent developments and results lead us to believe we can still increase the performance of the shaped charge warhead considerably. It seems, however, in view of the uncertainties involved since such a great number of variables must enter the analyses, that the warhead's actual effectiveness will not be known until it is tested against flying aircraft. Our task, of course, is to perfect the most efficient design within the limitations of the present warhead dimensions.

Future Plans

Future work will be directed along the lines of testing square and hexagonal cones made from larger than 5 1/2" cones in hopes that the target damage will be reduced only slightly and will be more than compensated by the increased number of cones in the warhead and the solid packing of the outer face as a result of these fitted cones.

Another phase we consider important is the optimum thickness for a given standoff. A thin cone which performs well at 60 ft. standoff, but

unsatisfactorily at 80 ft., may well be inferior to one which produces less damage at 60 ft. but satisfactory damage at 80 ft.

An axially initiated charge containing a 5" aluminum cone was fitted with a lead wave shaper which was calculated to change the expanding cylindrical detonation wave ordinarily impinging upon the cone to a plane wave. The results seemed encouraging enough to warrant further investigation. The principal drawback of a wave shaper in the warhead is that an amount of explosive equal to the volume of the shaper is forfeited.

Further work since the warhead test with larger pipe sections and wedges points to the conclusion that these liners are inferior in performance to cones. We believe, however, that hemispheres should be tested. This will be done if we are able to manufacture or obtain them.

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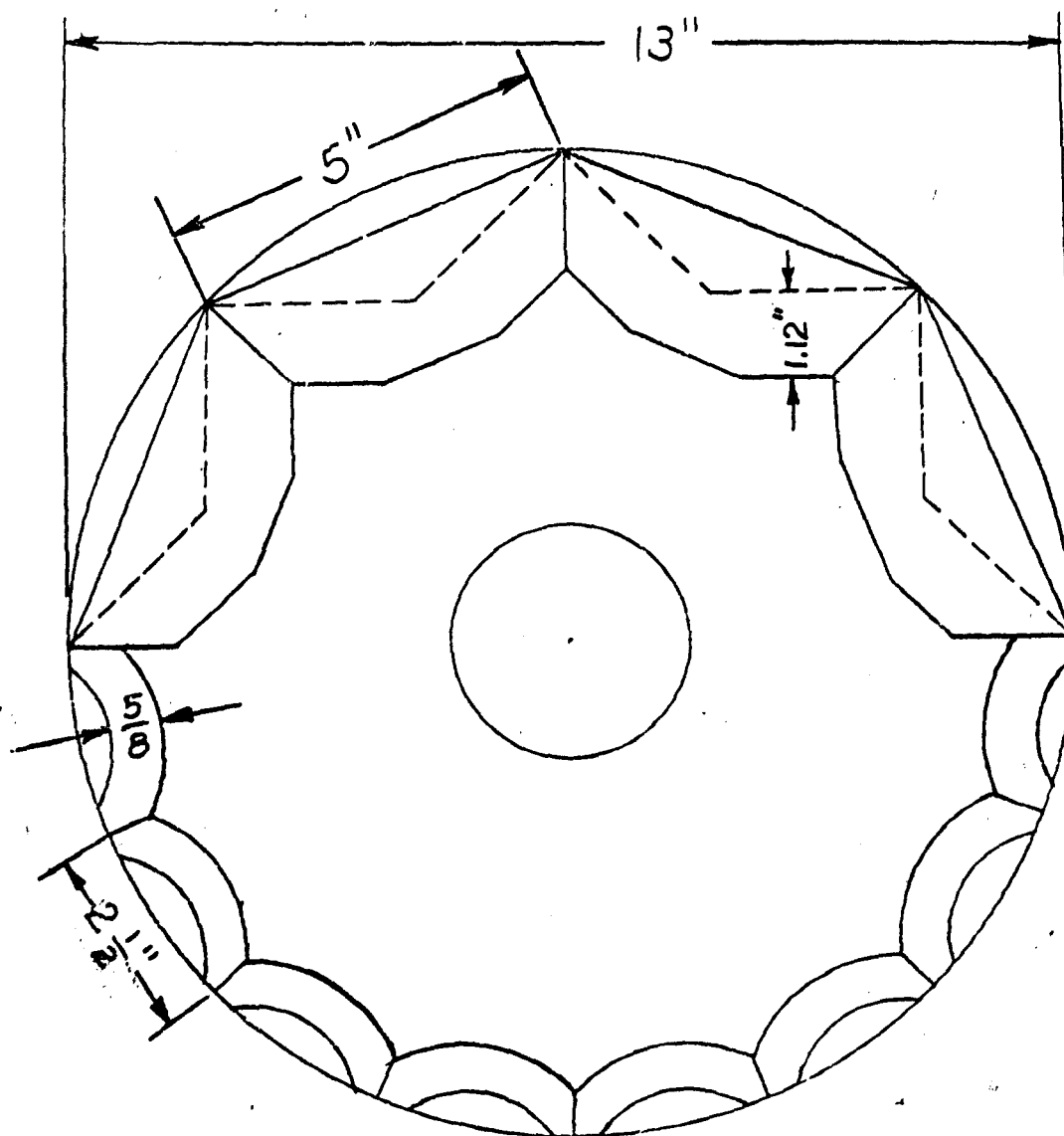
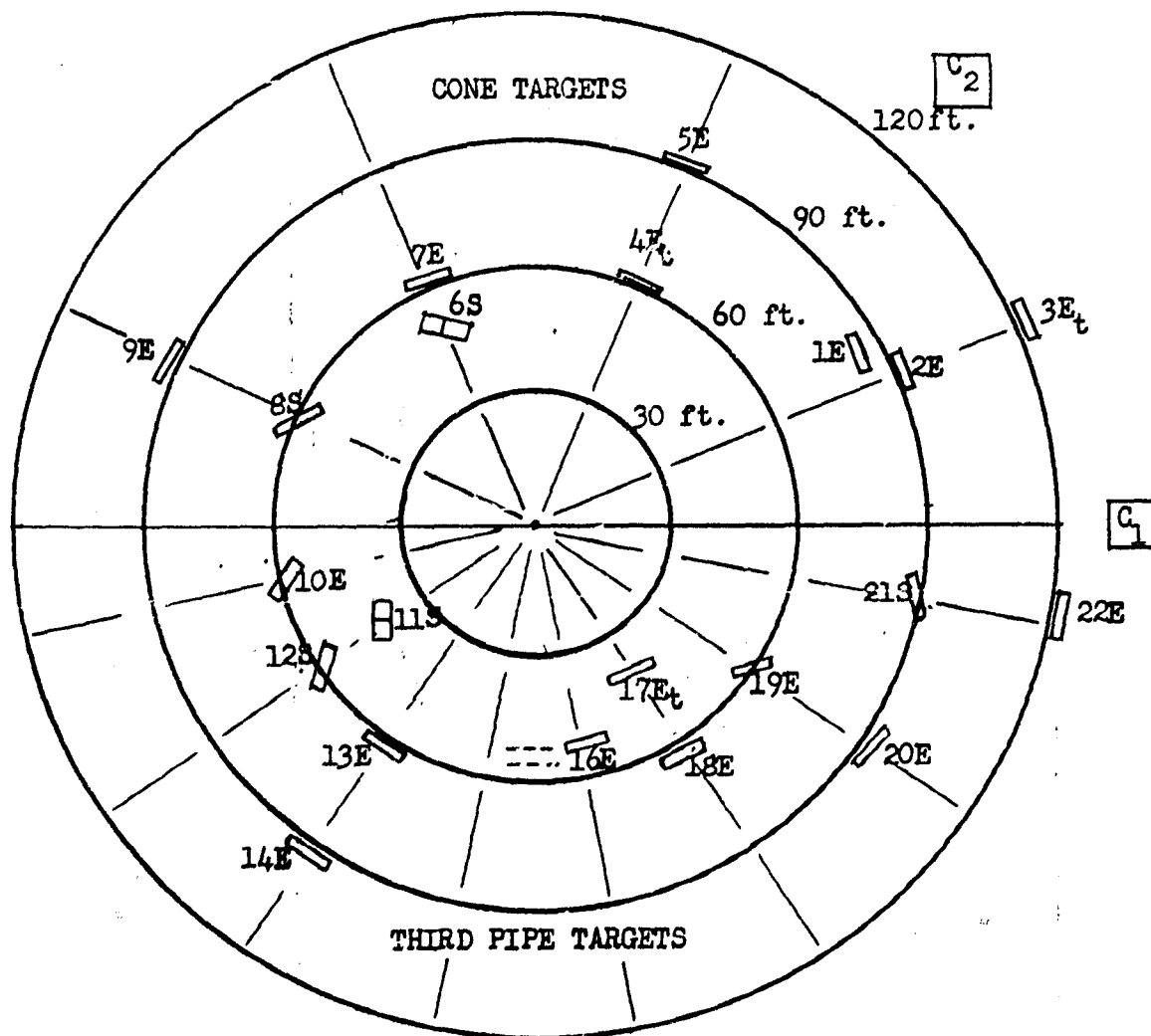


Fig. 1: Cross-sectional view of warhead showing one hemicylinder of cones and one of third pipes. Model I initiator at center (1 cm = 1 inch).

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S - on side in vertical plane
 E - on end in vertical plane
 Et - on end, tipped 30°-45°
 from vertical

— F-84 wing
 — B-17 horizontal stabilizer
 --- F-84 ailerons

Fig. 2: Diagram of test arena showing type of target and orientation.

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(a) Test area from camera C₁



(b) Closeup of warhead

Fig. 3: Views of the Target Area prior to Firing.

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Fig. 4: Open Shutter Photograph of Exploding Warhead.



Fig. 5: Test Area Immediately after Firing Warhead.

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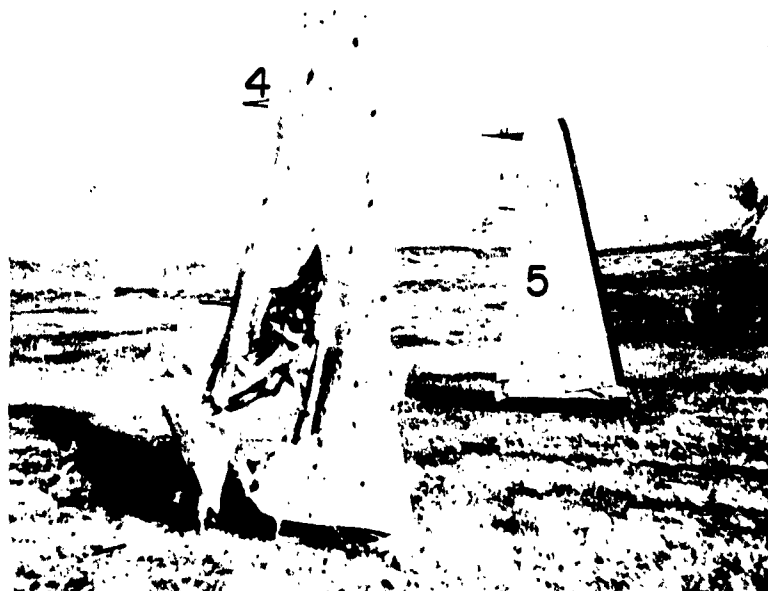


Fig. 6: Target Damage Photographs (Surfaces Restored to Pre-firing Positions).

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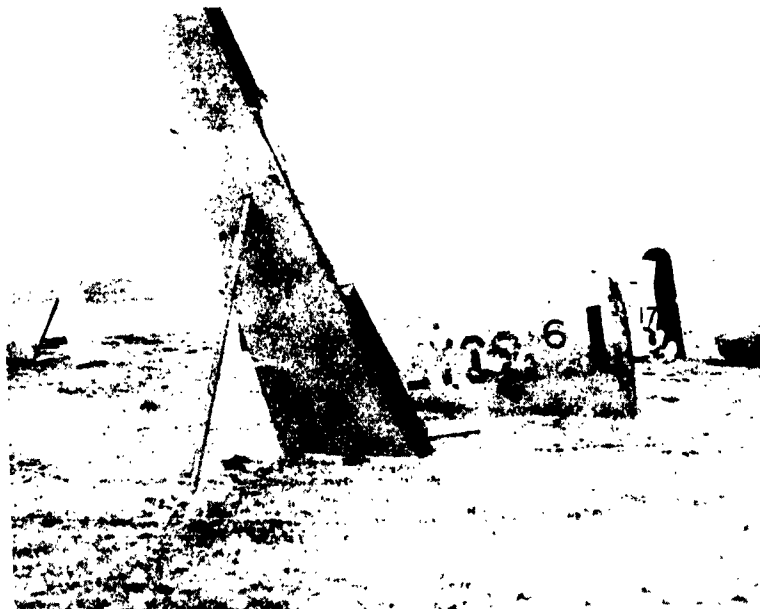
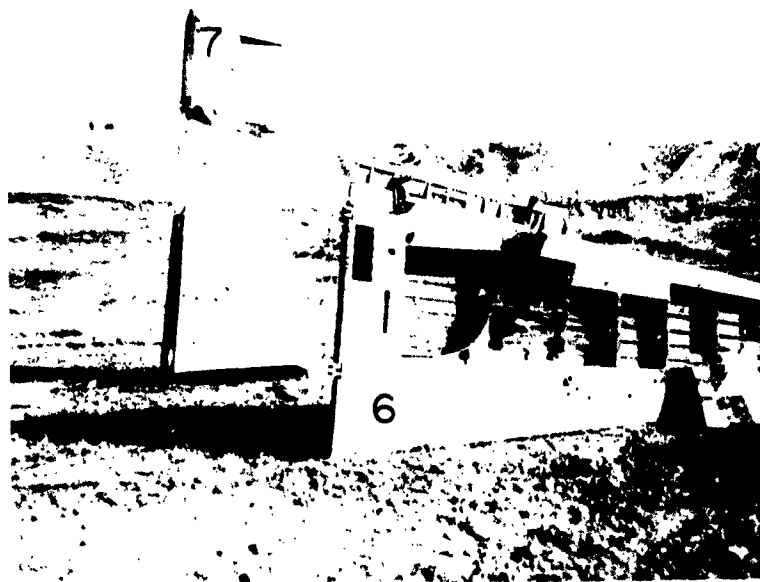


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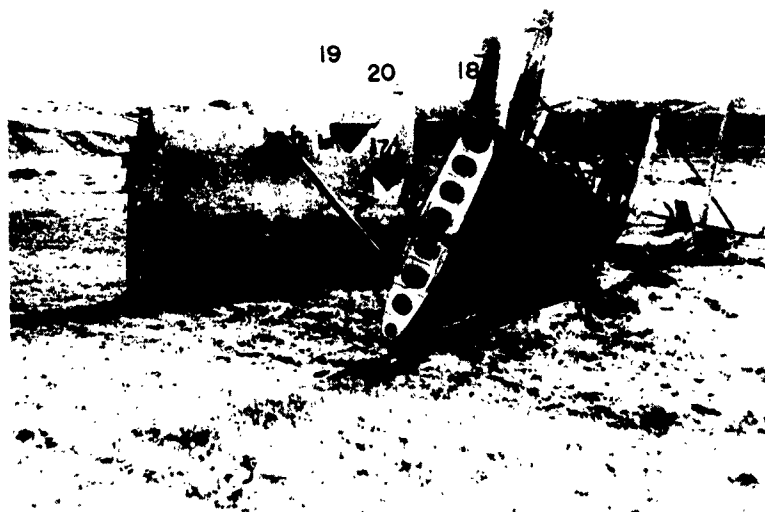


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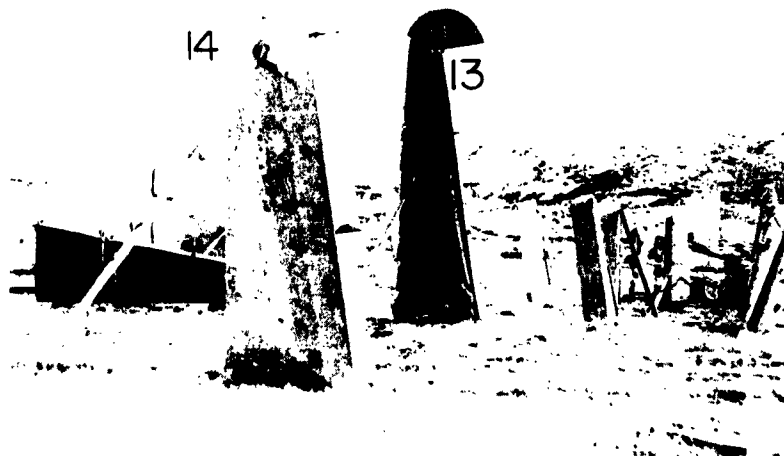
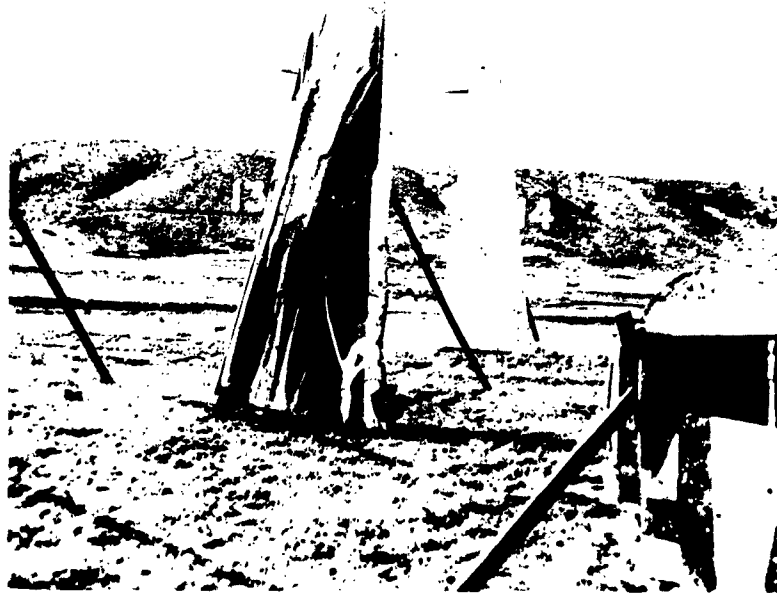


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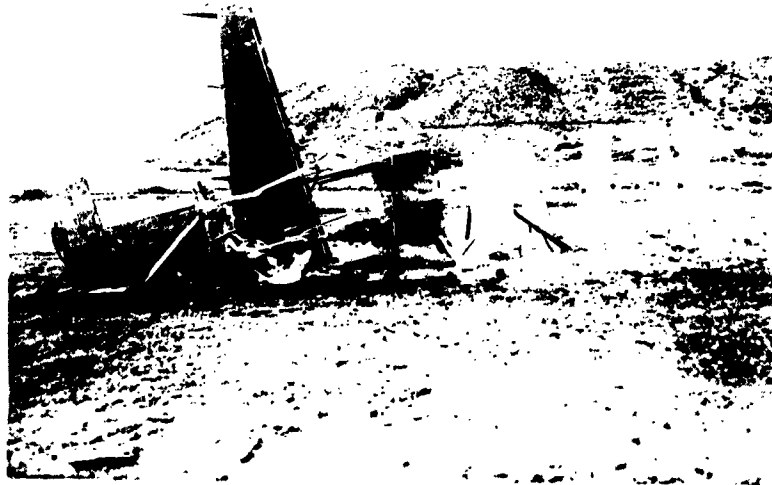


Fig. 6: Target Damage Photographs (Surfaces Restored to Pre-firing Positions).

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Fig. 6: Target Damage Photographs (Surfaces Restored to Pre-firing Positions).

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